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The Automation Control System Design of Walking Beam Heating Furnace

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Abstract: Combining the transformation project of certain strip steel rolling production line, the techniques process of walking beam heating furnace was elaborated in this paper. The practical application of LOS-T18-2ZC1 laser detector was elaborated. The network communication model of walking beam heating furnace control system was designed. The realization method of production process automation control was elaborated. The entire automation control system allocation picture and PLC power distribution system picture of walking beam heating furnace were designed. Charge machine movement process was elaborated. Walking beam movement process was elaborated. Extractor movement process was elaborated. The hydraulic station of walking mechanism was elaborated. Relative control circuit diagram was designed. The control function of parallel shift motor, uplifted and degressive motor was elaborated. The control circuit diagram of parallel shift motor of charge machine and extractor of first heating furnace was designed. The control circuit diagram of uplifted and degressive motor of charge machine and extractor of first heating furnace was designed. The realization method of steel blank length test function was elaborated. The realization method of tracking and sequence control function of heating furnace field roller were elaborated. The design provides important reference base for enhancing walking beam heating furnace control level.

Keywords: Walking beam heating furnace, Automation control system, Network communication model, PLC power distribution system, Motor control.

1. Introduction

Hot treatment must be done on steel blank before rolling so as to ensure rolling temperature and refining steel blank inner grain crystal structure. Heating furnace is the hot treatment equipment must be equipped in steel rolling industry. With the development of industry automation technology, large and highly automatical walking beam heating furnace should be equipped in modern steel rolling mill so as to enhance the quality and market competition power of product.

Walking beam heating furnace was designed by American Surface Combustion Corporation. It was imported by Japan Abroad Furnace Corporation before long. From that time, walking beam heating furnace was adopted generally on many steel rolling mills all over the world. It becomes key equipment

on steel rolling line [1]. Walking beam heating furnace is the heat treatment equipment designed to satisfy steel rolling techniques. Walking beam heating furnace is a kind of continuous heating furnace. Steel blank can be moved and advanced by the movement of ascending, advancing, descending and retreating of walking beam. The meaning of walking is transporting steel blank from furnace inlet to furnace exit periodically. Steel blank can be heated to rolling techniques requirement temperature at furnace exit. Relative control system is the key to ensure reliable production of walking beam heating furnace. Two walking beam heating furnaces were researched in this paper. The heating capability of each heating furnace is 260 ton an hour. The furnace inner steel blank temperature is about 1450 °C.

2. The Techniques Process of Walking Beam Heating Furnace

Firstly, steel blank enters front furnace roller. The check and centering of steel blank were completed in this stage. Front furnace roller contains adjacence roller and loading roller. Adjacence roller was named as A roller. It contains four set rollers that are A1 to A4 respectively. Loading roller was named as B roller. It contains five set rollers that are B1 to B5 respectively. A roller is the opening roller heating furnace field. The length test and check of steel blank were completed in A roller. The centering of steel blank before heating furnace was completed in B roller so as to transport steel blank to heating furnace front accurately. Then charge machine and loading steel furnace gate coordinating move to put steel blank on the appointed position of fixed beam of heating furnace. Last, steel blank was transported forward according to certain step distance that is 500 mm by walking beam cycle movement.

There are two LOS-T18-2ZC1 laser detectors. They were equipped on every heating furnace. One laser detector was used to realize location and length test of steel blank during loading. Another laser detector was used to realize steel blank location on heating furnace exit. When steel blank was detected by laser detector on heating furnace exit and also required from rough rolling field at the same time, extractor and extracting steel furnace gate coordinating move to transport heated steel blank on blank exit roller. Blank exit roller was named as C roller. It contains seven set rollers that are C1 to C7 respectively. Then steel blank was transported to rough rolling field by C roller movement.

3. LOS-T18-2ZC1 Laser Detector

LOS-T18-2ZC1 laser detector is high power laser detector. It was mainly used to detect whether steel blank was located on special heating furnace position or not. Meanwhile switch quantity control signal was outputted so as to realize control function. It is suitable for metallurgy industry heating furnace work environment. Big power semiconductor infrared laser was adopted as emitter. After modulating, a beam strong laser was emitted. The emitted laser was received by phototube. After amplification processing, a control signal was outputted. Emitter has the characteristics of big transmitting power, penetrating high temperature heating furnace, far function distance and strong capacity of resisting disturbance. The optical lenses of emitter and receptor were all made of thermostability quartz glass.

Installation picture of LOS-T18-2ZC1 laser detector was shown as Fig. 1. Electronic part of emitter was shown as Fig. 2. Emitter optics lenses was shown as Fig. 3. Receptor optics lenses were shown as Fig. 4. Electronic part of receptor was shown as Fig. 5. Relative emitting mode was adopted on this laser detector. Firstly, the optics lenses and electronic parts of emitter and receptor were installed well. Then optical fibers were used to connect optics lenses and relevant electronic parts. After connecting electric source, optics lenses of emitter and receptor were adjusted so as to realize accurate collimation. 300 Hz infrared laser was modulated and emitted by electronic part of emitter. Electronic part of receptor was modulated to 300 Hz so as to receive. When steel blank has not entered detection area, normal signal can be received by receptor. Reception energy pilot lamp was lit. Output status is normal. When steel blank has entered detection area, normal signal can not be received by receptor. Reception energy pilot lamp was not lit. Output status is abnormal. Owing to infrared modulated high frequency laser, this laser detector has good capacity of resisting disturbance. Relevant movement is reliable.

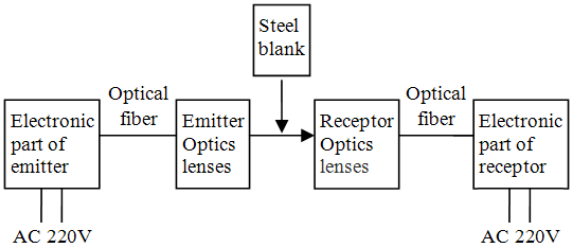

Fig. 1. Installation picture of LOS-T18-2ZC1 laser detector.

Fig. 2. Electronic part of emitter.

Fig. 3. Emitter optics lenses.

Fig. 4. Receptor optics lenses.

Fig. 5. Electronic part of receptor.

The main performance parameters of LOS-T18-2ZC1 laser detector are as follows. Detection area is no more than 50 meters. Emitter is infrared semiconductor laser. Laser wavelength is 95 nm. Emitter peak value output power is 150 Watts. Laser security classification is CLASS IIIb. Level signal response time is no more than 15 milliseconds. Node signal response time is no more than 100 milliseconds. Supply voltage is AC 220 V. Environmental temperature range is -25 °C to 70 °C.

4. The Entire Automation Control System and PLC Power Distribution System of Walking Beam Heating Furnace

The key of walking beam heating furnace control system are series PLC provided by America GE Corporation. There are three kinds of network communication models. They are internal memory reflection network, Ethernet and GENIUS network. The communications among heating, rough rolling and finish rolling were realized by internal memory reflection network. The communications among heating furnace inner PLC were realized by Ethernet. The communications between PLC and HMI were realized by Ethernet. The communications between PLC and long distance station were realized by GENIUS.

There are six computers in heating furnace field. They were used on the operation of instrument, electrical device and vaporization respectively. The CIMPLICITY system of America GE Corporation was adopted on exploiting function menu. All kinds of production process parameters of temperature, pressure and flux and so on can be monitored by relative function menu in operation station. The production process automation control can be realized by equipment instrument monitoring system, electrical device monitoring system and vaporization monitoring system of heating furnace field. The entire automation control system allocation picture of walking beam heating furnace was shown as Fig. 6. The power supply of all PLC systems in heating furnace field was realized by a USP. The entire PLC power distribution system picture of walking beam heating furnace was shown as Fig. 7.

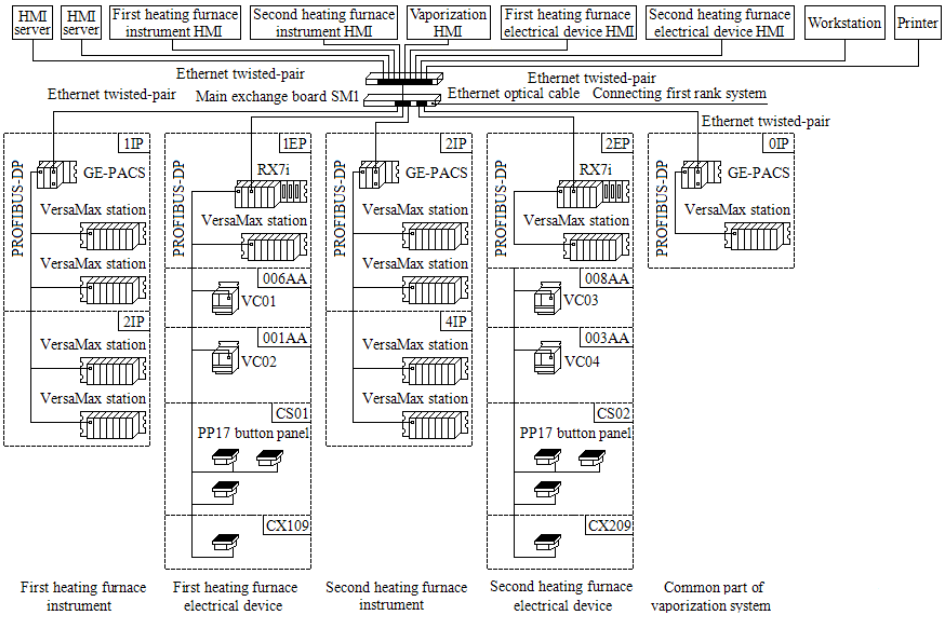

Fig. 6. The entire automation control system allocation picture of walking beam heating furnace.

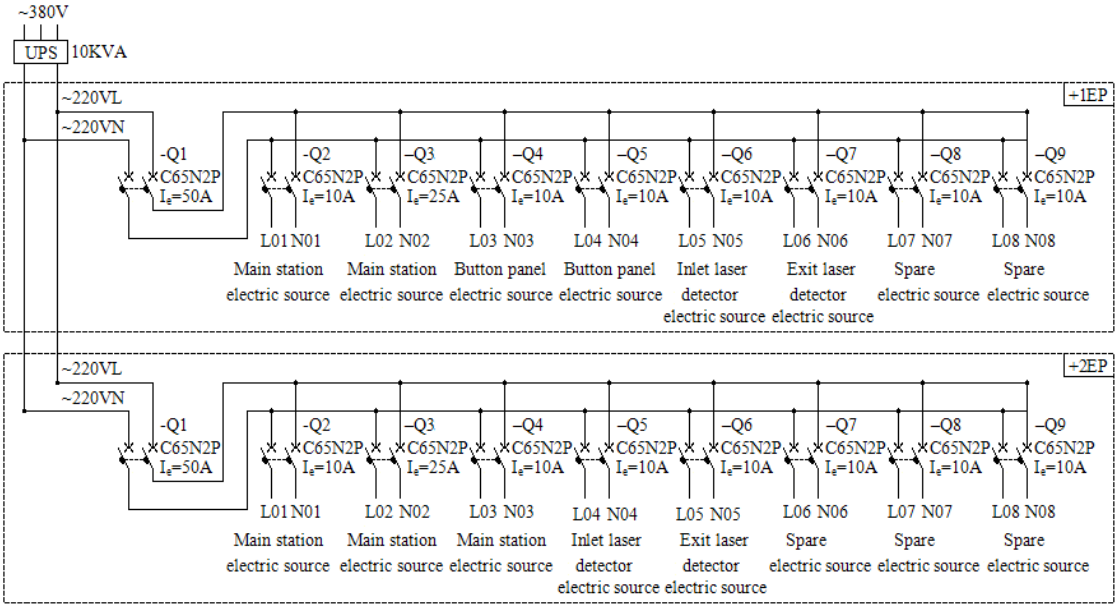

Fig. 7. The entire PLC power distribution system picture of walking beam heating furnace.

5. Charge Machine Movement Process

The movement distance of front charge machine of walking beam heating furnace is 10 meters. Charge machine was shown as Fig. 8.

Fig. 8. Charge machine.

Charge machine movement mechanism contains parallel shift, uplifted and degressive mechanism. Charge machine movement contains five parts. They are pushing steel, uplifting steel, transporting steel, putting steel and return. In pushing steel process, after obtained centering finish signal of steel blank on loading roller, charge machine begin to move parallel and push steel blank. When charge machine front overstepping loading roller 50 mm, charge machine stops. It can ensure that steel blank was transported to an accurate position. Relative charge machine movement distance S_p was shown as formula (1).

$$S_p = 1925 - B, \tag{1}$$

where B is the steel blank width, S_p is the parallel movement distance.

In uplifting steel process, the uplifted and degressive mechanism of charge machine moves. Steel was uplifted and left roller certain distance. The uplifting steel order and opening loading gate order were emitted by PLC simultaneously. In transporting steel process, the parallel shift mechanism of charge machine moves. Steel blank was transported to heating furnace inner. When the distance between current steel blank and previous steel blank is 50 mm, charge machine stops. Relative charge machine movement distance S_c was shown as formula (2).

$$S_c = 3915 + X_{m+1}, \tag{2}$$

where X_{m+1} is the distance between the m+1 steel blank end and fixed beam end.

In putting steel process, the uplifted and degressive mechanism of charge machine moves. Steel was put on walking beam and descended to inferior limit position. In return process, the parallel shift mechanism of charge machine returns its original position with maximum speed. When the distance to original parallel shift mechanism position is 1.8 meter, the closing loading gate order was emitted by PLC.

6. Walking Beam Movement Process

According to techniques requirement, hydraulic inclined double wheel rail drive mode was adopted by walking mechanism. The uplifted and degressive movement of kinetic beam was driven by double fluid cylinder synchronously. The horizontal shift of horizontal beam was driven by horizontal fluid cylinder. The uplifted and degressive movement of uplifted and degressive beam was driven by vertical fluid cylinder. The structure lateral picture of walking mechanism was shown as Fig. 9.

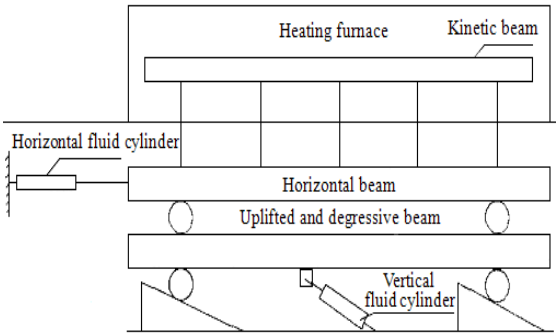

Fig. 9. Structure lateral picture of walking mechanism.

During running process, walking mechanism speed control was realized by adjusting oil flux in fluid cylinder [2]. Owing to the big flux and high pressure of oil in hydraulic system, electro-hydraulic proportional valve was adopted. The power was provided by a set of separate hydraulic station. The hydraulic station can satisfy relative requirements of step distance, speed and impact load during all kinds of walking beam cycle movements. The control circuit diagrams of the first main pump to the third main pump of hydraulic station were shown as Fig. 10, Fig. 11 and Fig. 12 respectively. The control circuit diagram of the first cycle pump of hydraulic station was shown as Fig. 13.

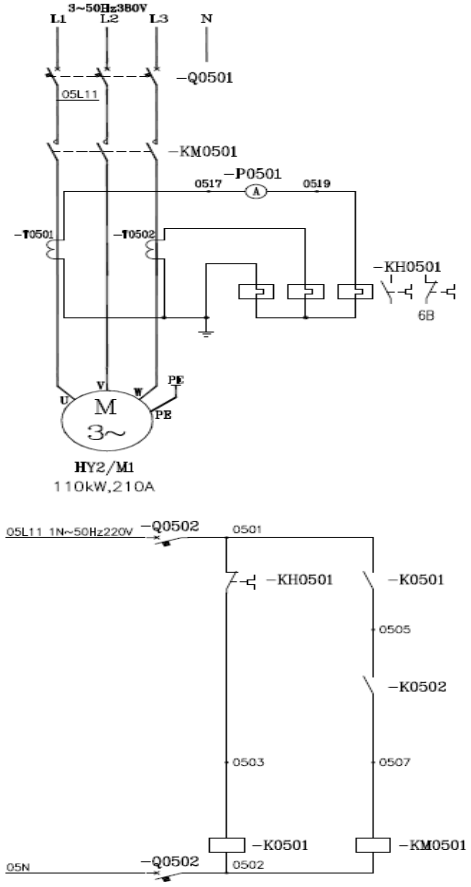

Fig. 10. The control circuit diagram of the first main pump of hydraulic station.

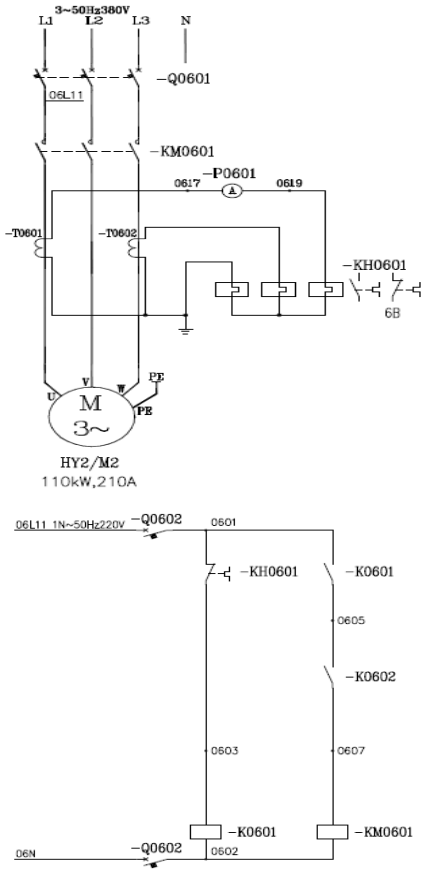

Fig. 11. The control circuit diagram of the second main pump of hydraulic station.

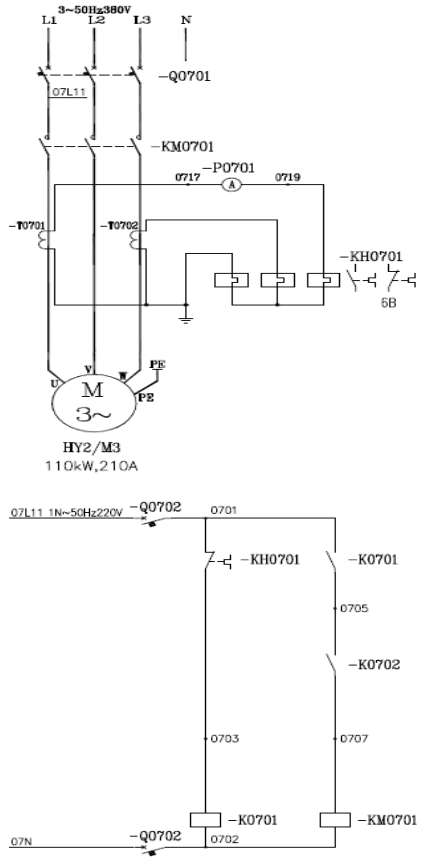

Fig. 12. The control circuit diagram of the third main pump of hydraulic station.

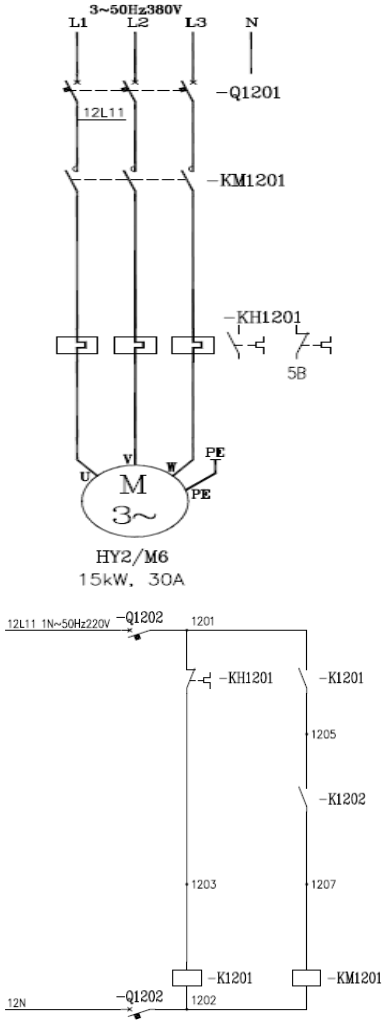

Fig. 13. The control circuit diagram of the first cycle pump of hydraulic station.

After charge machine loading finish, according to actual condition, one of the follow movements may be chosen by walking beam to begin cycle movement from its original position. Positive cycle movement was chosen usually. It contains the movements of ascending, advancing, descending and retreating. A step distance that is 500 mm was advanced on steel blank in heating furnace by positive cycle movement. Manual reverse cycle movement was chosen during fault. It contains the movements of advancing, ascending, descending and retreating. A step distance that is 500 mm was retreated on steel blank in heating furnace by reverse cycle movement. When waiting rolling time is less than one hour, stepping movement was adopted. It contains the movements of ascending to limit position, postponing and descending. In heating furnace, steel blank was stepped on its original position by stepping movement. When waiting rolling time is more than one hour, accordant stepping movement was adopted. It contains the movements of ascending to fixed beam height, postponing and descending. In heating furnace, steel blank was stepped on its original position by accordant stepping movement.

7. Extractor Movement Process

Front extractor of heating furnace was shown as Fig. 14.

Fig. 14. Front extractor of heating furnace.

Extractor motion mechanism contains parallel shift mechanism and uplifted and degressive mechanism. When forward command was sent by PLC, quick parallel shift of extractor lever from original position to heating furnace was implemented. When lever is near to steel blank, parallel shift motor decelerates and stops at target position. When forward command was sent by PLC, heating furnace gate opening command was also sent by PLC. When up command was sent by PLC, extractor uplifted and degressive motor work. Lever and steel blank were uplifted. When backward command was sent by PLC, steel blank was extracted and moved parallel from heating furnace by extractor lever. Extractor lever returns to original position. When the distance between extractor lever and its original position reaches set value, heating furnace gate shut command was sent by PLC. When fall command was sent by PLC, extractor uplifted and degressive motor work. Lever and steel blank were dropped. Steel blank was put on table roller [3-8]. The whole tapping process can be accomplished by above operations.

8. The Control of Parallel Shift, Uplifted and Degressive Motors of Charge Machine and Extractor

The parallel shift motor control circuitry of charge machine and extractor of first heating furnace was shown as Fig. 15. The controls of corotation startup, corotation stop, reversal startup, reversal stop, overload protection, frequency conversion and banding brake of parallel shift motor can be realized by relative control circuitry. Inverter wiring diagram was shown as Fig. 16. The uplifted and degressive motor control circuitry of charge machine and extractor of first heating furnace was shown as Fig. 17. The controls of corotation startup, corotation stop, reversal startup, reversal stop, overload protection and banding brake of uplifted and degressive motor can be realized by relative control circuitry.

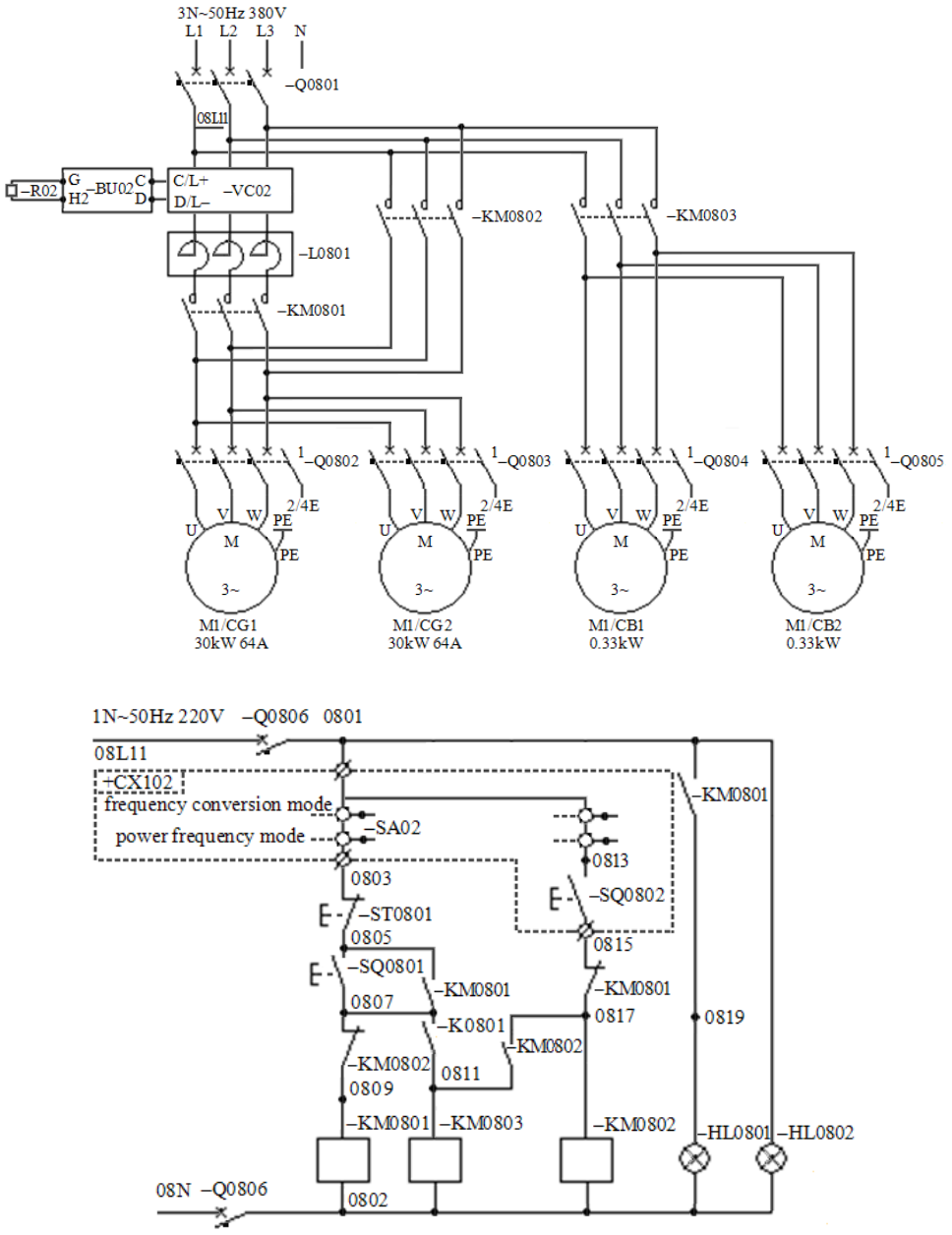

Fig. 15. The parallel shift motor control circuitry of charge machine and extractor of first heating furnace.

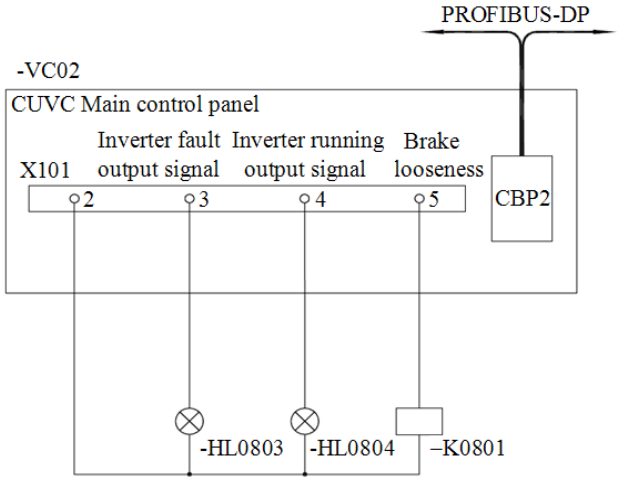

Fig. 16. Inverter wiring diagram.

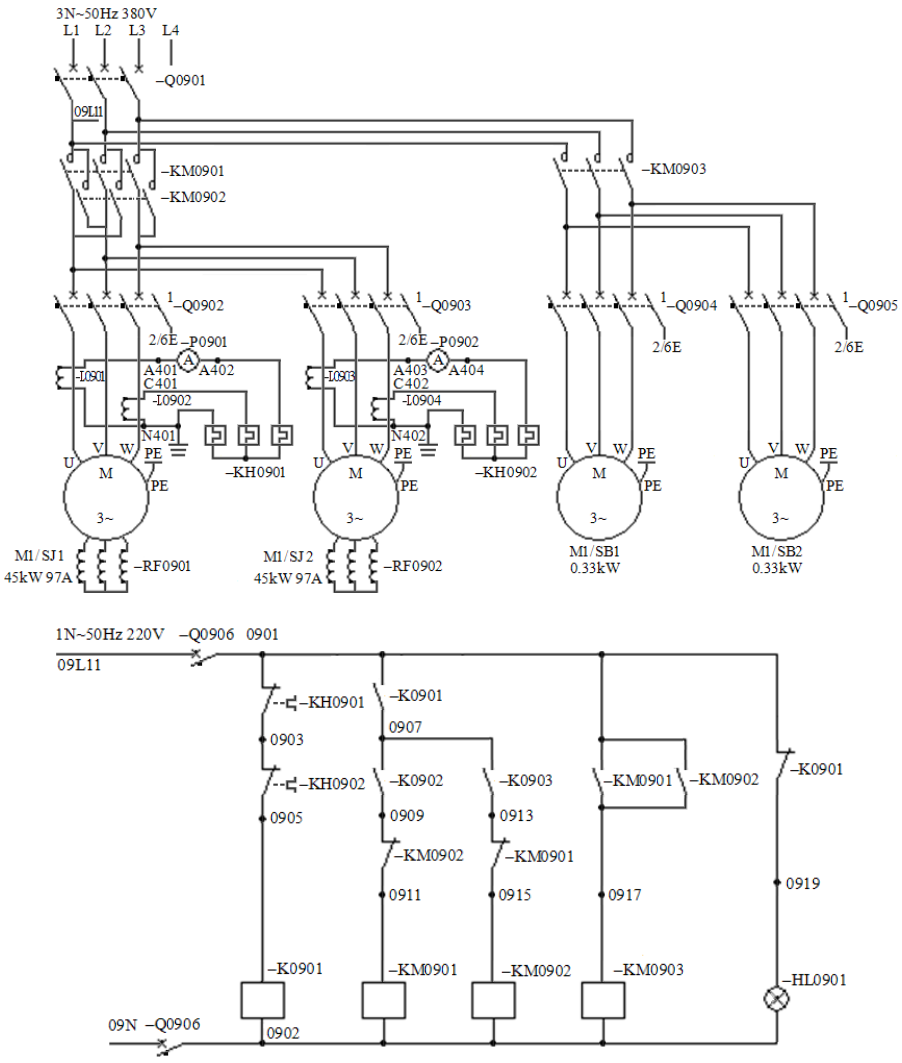

Fig. 17. The uplifted and degressive motor control circuitry of charge machine and extractor of first heating furnace.

9. The Tracking and Sequence Control of Heating Furnace Field Roller

9.1. The Realization Method of Steel Blank Length Test

Pulser and laser detector were installed on A1, A2, A3 and A4 adjacence rollers. Pulser was used as record steel blank movement distance. Laser detector was used as check the top and end positions of steel blank. When the top position of steel blank was checked, the impulse number collected by high speed counting template was reset. The collected impulse number increases with steel blank passing distance simultaneously. When the end position of steel blank was checked, steel blank length can be calculated by impulse number and impulse increment.

9.2. The Realization Method of Heating Furnace Field roller Tracking Function

When steel blank enters certain roller, detector was covered. Then steel existence signal was produced. Steel blank data were entered into relative roller data flow. When steel blank leaves certain roller, detector was not covered. Then steel inexistence signal was produced. Steel blank data were dislodged from relative roller data flow. Steel blank data in PLC were changed with continuous running of steel blank among rollers accordingly. By this way, the tracking function of heating furnace field roller can be realized.

9.3. The Realization Method of Heating Furnace Field Roller Sequence Control Function

When steel blank movement distance from current roller to next roller reaches definite distance, next rollers were started. When steel blank enters next rollers, it can ensure the same speed of current rollers and next rollers. This can avoid unnecessary roller empty running. So energy was saved. Roller working life was lengthened. By this way, the sequence control function of heating furnace field roller can be realized.

10. Conclusions

The practical application of LOS-T18-2ZC1 laser detector was elaborated in this paper. The network communication model of walking beam heating furnace control system was designed. The realization method of production process automation control was elaborated. The entire automation control system allocation picture and PLC power distribution system picture of walking beam heating furnace were designed. Charge machine movement process was elaborated. Walking beam movement process was elaborated. Extractor movement process was elaborated. The hydraulic station of walking mechanism was elaborated. Relative control circuit diagram was designed. The control function of parallel shift motor, uplifted and degressive motor was elaborated. The control circuit diagram of parallel shift motor of charge machine and extractor of first heating furnace was designed. The control circuit diagram of uplifted and degressive motor of charge machine and extractor of first heating furnace was designed. The realization method of steel blank length test function was elaborated. The realization method of tracking and sequence control function of heating furnace field roller were elaborated. After practice test, the design can satisfy the walking beam heating furnace field automation control requirement. The design enhances continuous strip steel rolling productivity obviously.

Acknowledgements

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