Application of ALPHA6900 Inverter in Hoister in Inclined Shaft of Mines

Introduction

Mine hoisting includes shaft hoisting and incline hoisting, and a mine hoist, called the “throat” of the mine, is essential equipment in mine production. It is responsible for hoisting and putting down ore, barren rocks, equipment, materials and personnel. It plays a very important role in mine production.

The incline hoist for the 3-2 ore body used by * Group has adopted the traditional AC (alternating current) speed regulation method of rotor winding series resistance. This speed regulation method has the following shortages: first of all, it has used many electromagnetic relays, which will take a long time to determine and rule out faults, and after long operation, it has a high failure rate, which does not only ask for a high cost of maintenance but also impacts the extracted ore tonnage; secondly, the automation degree of the hoist is low, there is loud noise during operation, the hoist room has a high temperature, the driver of the hoist tends to get tired, and the labor intensity is high; thirdly, during continuous lifting of heavy weights with low speed, the resistance tends to be overheated, which tends to burn the resistance connection wire and have huge energy consumption; fourthly, the speed regulation is step speed regulation, which tends to cause a big mechanic shock on the steel wire rope and speed reducer.

1. Solution and System Composition

1.1 Solution

An AC (alternating current) speed regulation system consisting of frequency-conversion speed regulation device, PLC (programmable logic controller), energy feedback unit and touch screen has been adopted to replace the original series-resistance speed regulation system.

1.2 System Composition

Functional block diagram of system composition is shown in FIG. 1:

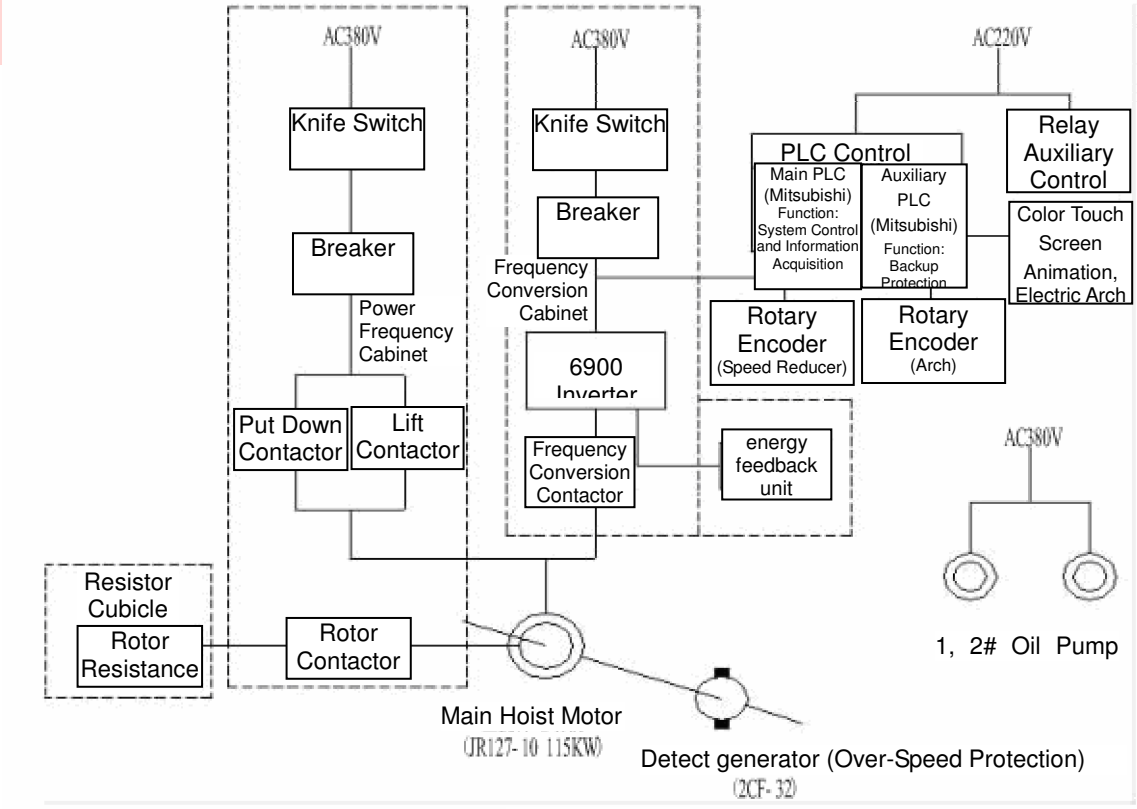


Fig 1

The frequency-conversion circuit includes: knife switch, breaker, inverter, contactor below the inverter and the energy feedback unit, of which, the energy feedback unit composes one cabinet.
Control circuit: it mainly consists of main PLC control, auxiliary PLC control, touch screen, relay auxiliary control and operation panel, of which, the main PLC control and auxiliary PLC control compensate each other, the relay auxiliary control, main PLC control and auxiliary PLC control are installed in the same control cabinet, and the touch screen is installed on the operation panel as the upper computer. As the feedback signal of location and speed, the encoder is installed in the motor and hoisting drum. The speed-measuring encoder installed in the motor feeds back the signal to the inverter, which constitutes a PG vector control; another encoder feeds back a signal to the PLC to calculate the speed and location. The signals of the speed-measuring motor, oil temperature, oil pressure and other switching values enter the PLC system.

2 System Functions

2.1 System functions under the four states of stop, automatic, manual and slide state

Stop: Under this state, the system will stop working, non operation can be conducted, and the winch is under the block braking state.
Manual: Under this state, when the system satisfies safe operation, normal up and down manual operations are conducted to the winch through master controller.
Automatic: Under this state, the Up and Down buttons automatically complete the whole process of up and down, and during its trip, manual intervention can be conducted to stop its motion by pressing the Stop button, and it can be restarted by pressing the Up and Down buttons again.
Slide: When the system has a serious fault and cannot be used with up and down operations, the function switch should be switched to this location, and the winch can slide to the confirmed location through the master controller.
Winch double-wire protection and controls required in the “Safety Regulations for Coal Mines” are realized through double PLC digital control technology. Winch double-wire protection and controls have the following characteristics:
(1) High precision of speed regulation, wide range of speed regulation, the speed regulation precision is no smaller then 0.05%
(2) Double-wire protection: one hardware safety circuit and two software safety circuits redundant to each other are adopted, which makes the system safer and more reliable.
(3) Double-wire control: during normal operation, due to adoption of the double PLC systems which are mutual monitoring and redundant to each other, when one PLC system has fault, another PLC system can still be put into use to conduct emergency start, which can improve the operation reliability of the winch system.

2.2 Protection and Interlock Function

2.2.1 During safety braking, coordinate with the safety valves in hydraulic station to realize primary and secondary braking, and in the meantime, the inverter enters the feedback braking state.
2.2.2 Under any situation, the hoist can only be operated after the driver has received the start signal.
2.2.3 During the hoisting process, if there is a situation like the lubricating oil pressure is too high or too low, or the lubricating oil filter or hydraulic station filter has a blockage or its oil temperature is too high, the touch screen will indicate the corresponding message of failure, and the corresponding

information light will be turned on to inform the driver that this hoisting operation can be completed, but the next hoisting operation can only be conducted once the failure is eliminated.

2.2.4 When the hoist stops during the travel due to failure, and if the hoisting conveyance is within the reduction travel, after the failure has been eliminated, the driver is allowed to choose starting toward the last direction before the stop, and it can only be driven in low speed; if the hoisting conveyance is not within the reduction travel, send start signal at the mine entrance, and allow the driver to drive in high speed.

2.2.5 When the whole mine has a power failure, the PLC system can ensure that the hoist can realize secondary braking, and backup protection of the hoist is also properly done.

2.2.6 The operation braking torque of the disk brake is adjustable. The emergency braking (safety braking) can generate secondary braking to avoid mechanical shock.

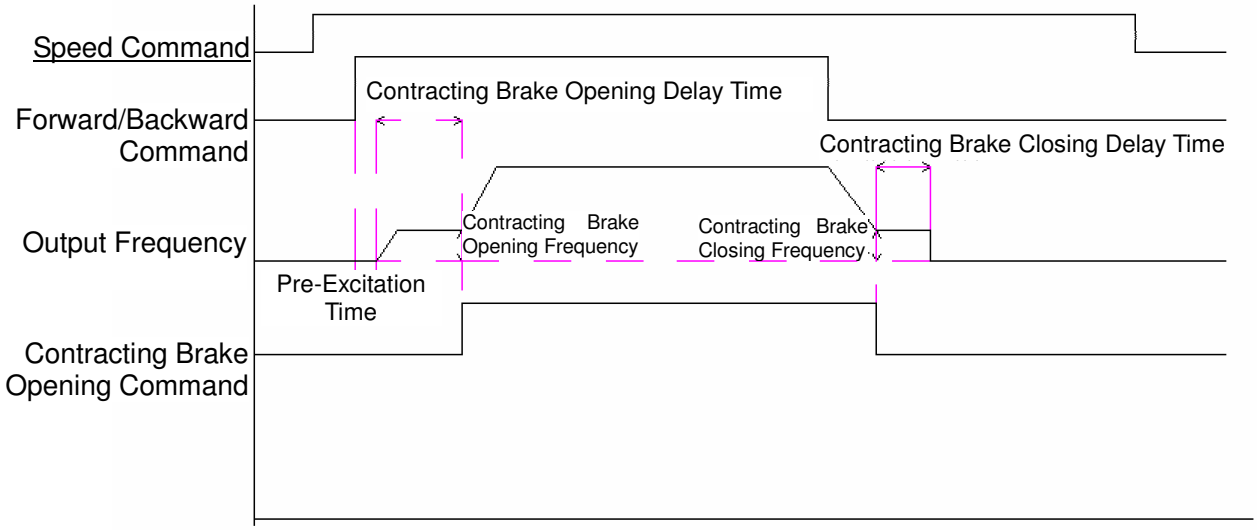
2.3 Process Control Function

Process control is conducted by the PLC system, which mainly divides the lifting process of the hoist into various intervals in accordance with different lifting speeds. Change the given value of speed in accordance with the actual situation and different speed requirements of each interval, and form a closed loop to smoothly regulate the lifting speed of the hoist. The process control can not only control the speed of the whole lifting process of the hoist, but also the stop and braking process of the hoist. The process control can prevent various accidents of the hoist such as over winding, over discharging, derailment and overturning from happening. It especially applies to special inclined shaft with curves and turnoffs.

2.4 Braking Control Function

Normal braking of the hoist includes feedback braking and contracting braking. Feedback braking is realized by introducing an inverted link into the DC link of the AC—DC—AC voltage type inverter. When the actual operation speed of the hoist is higher than the given operating speed, the motor equals a generator, the voltage of the DC link increases, which provides energy to the inverter and feeds back to the power system, and the motor automatically operates in a braking state to realize accurate stop of the inverter and also to well prevent mechanic shock and fast slide. Contracting braking is usually used during stops; when it moves to the stop position, the process controller sends a stop signal to the inverter, and in the meantime, it also sends contracting control signal to the contracting brake to realize contracting braking. When there is an accident such as derailment, the operation control conducts emergency contracting braking.

This system has adopted feedback braking. During the braking process, the hoist has stable operation and feeds back the braking energy to the power system, which has certain effect of energy conservation. The braking process of ALPHA6900 is shown in the following diagram.



3 Functions of Main Components

3.1 PLC (programmable logic controller) Function

Except the emergency protection function, all other system control is realized by programmable logic controller (PLC). The programmable logic controller equipped in the system can adapt to severe industrial environments, it has a strong anti-interference capacity and two communication ports (programmer port and universal port) which can be used at the same time, it can directly and conveniently show the system operation state, fault state and operation parameters through communication with the liquid crystal touch screen, and it can also show the state of all switching elements as well as information of failure and alarm; signals sent from the voltage transducer, current transducer and encoder equipped in the receiving system will be used to conduct control, monitoring and protection of the winch after calculation and processing. During emergency braking (safe braking), the PLC (programmable logic controller) controls the disk brake to generate secondary braking to avoid mechanic shock. FIG. 2 has shown the control flow diagram of the PLC (programmable logic controller) of a simplified system.

3.2 Inverter Function

The inverter receives speed feedback signal from the rotary encoder, forms PG vector control, and realizes stepless speed regulation of the motor. This system has equipped ALPHA6900 series inverter and energy feedback unit.

- Integrated plan: combination between motor driven and logic control of lifting is adopted to skip PLC of the original system, reduce potential spots of failure, simplify the system wiring and bring simple and flexible debugging, which presents the future development direction of hoist control;
- The wide voltage-range design can better satisfy severe power environment;
- Professional logic design of hoist: based on many years' design experience in the hoist industry, a control and safety logic with expert-level and widely used hoisting structure has been designed, including functions such as timing coordination and anti-running, and a perfect solution will be provided to the customers;
- There is a special fixed-length design is for the loading system in the mining, metallurgy and road

building industries, which makes the control safer and more reliable. Accurate torque control: stall prevention function and failure resetting and retrying function; installation and application of the rotary encoder ALPHA6900 can realize vector control of flux current in the whole frequency domain, and under 0.5Hz, 150% output torque of the motor can be maintained.

Main technical parameters of the frequency-conversion device:

(1) Input power voltage is AC304-456V, and the frequency is 50HZ; the allowed fluctuation range of voltage is +/-20%, and the allowed fluctuation range of frequency is 48-65HZ;

(2) The output frequency should be continuously adjustable within the range of 0～50Hz;

(3) Rated heavy load output power: 160kW;

(4) Overload capacity: 150%, 1 minute; 180%, 20s;

(5) When there is high power factor, cosφ＞0.98;

(6) During low-frequency operation, there is automatic torque boosting function and slip compensation function, which can ensure 150% of rated torque;

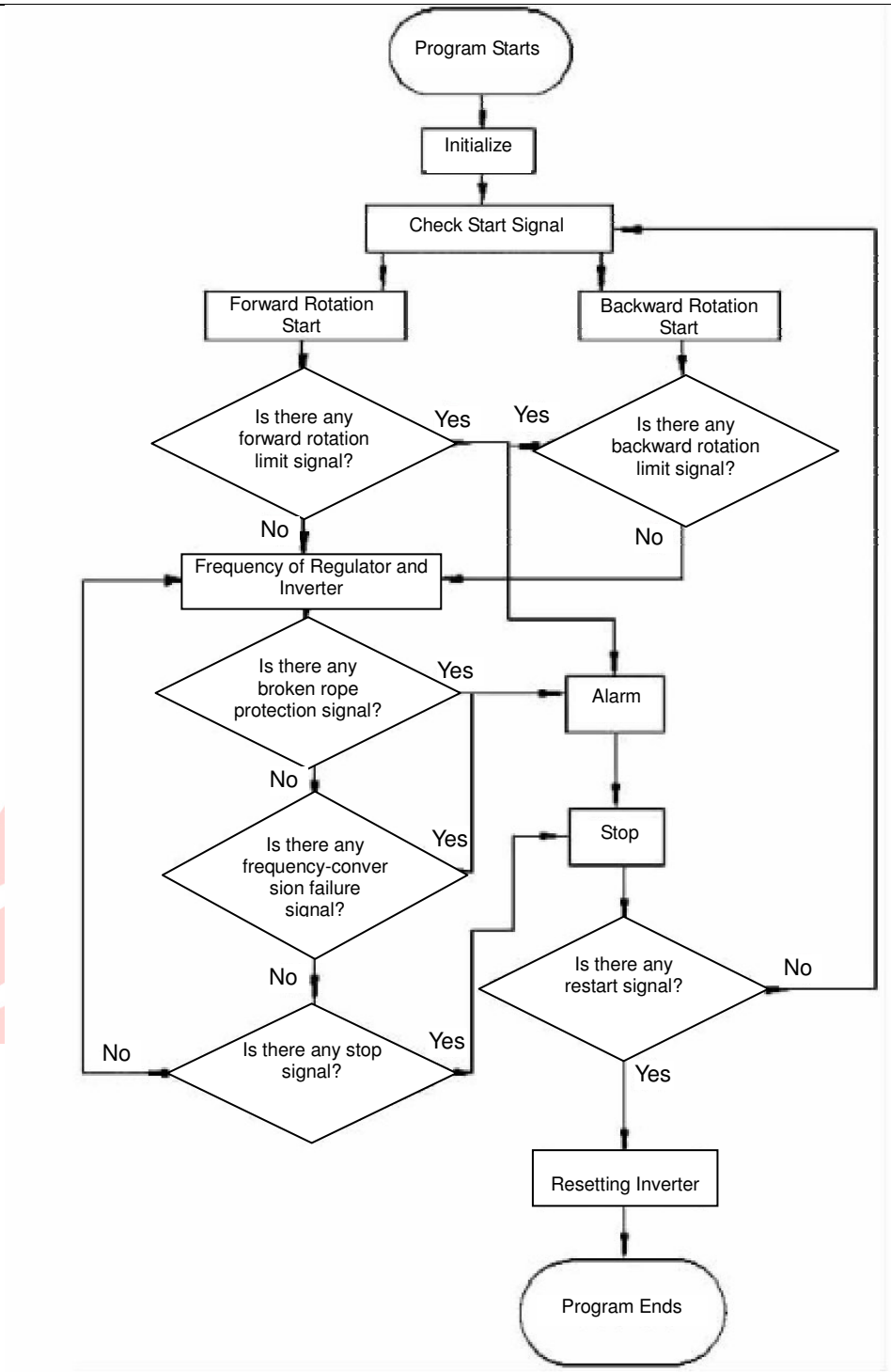
(7) The inverter is equipped with over-voltage, under-voltage, over-current, overload, overheating of component and motor lack-of-phase protection, and it is also equipped with failure memory function, which can save the last 5 functional codes of failure and the last failure parameter.

(8) Total harmonic content THD<5%.

Main Technical Principles

(1) All-digital speed sensor closed-loop vector control has been adopted to provide a wide range and high precision for system speed regulation. When the inverter operates under low frequency, more than 150 % of rated torque output can still be ensured. The maximum torque is twice the rated torque. The basic principle to realize vector control is to first measure and control the stator current vector of the asynchronous motor and then control the exciting current and torque current of the asynchronous motor in accordance with the field orientation theory, in this way realizing the purpose of controlling the torque of the asynchronous motor. The specific procedure is to divide the stator current vector of asynchronous motor into the current component (exciting current) which can generate a magnetic field and the current component (torque current) which can generate torque, and in the meantime, control the amplitude and phase of these two components, i.e., control the stator current vector, and this control mode is called vector control mode. In this way, a three-phase asynchronous motor can be controlled like a DC motor, and static and dynamic performances same as a DC speed regulation system can be obtained.

PLC control procedure is shown in FIG. 2.



3.3 Energy Feedback Unit

Its main purpose is to increase the braking capacity of the inverter, and feed back the braking energy to the power system when the winch puts down heavy weights for energy conservation.

3.4 Main Functions of the Operation Panel

The operation panel is installed with a manually operated master controller, and the braking force and operation speed of the winch can be regulated manually. It is also equipped with manual and pedal emergency braking switch, which is used to conduct fast breaking during emergency situation.

3.5 Function of the Liquid Crystal Touch Screen

Through communication with PLC (programmable logic controller), it can directly show the system operation state, fault state and operation parameters (such as the operation speed of the winch, location of the hoisting conveyance, motor current and voltage, etc.), it can show the state of all switching elements as well as various failures and alarm information, it can modify the internal parameter setting of PLC (it requires corresponding authority), it has password protection function, which can modify the operator password in accordance with setting of authority, and operators with different security levels have different operation authorities.

4. Selection of Main Components

4.1. Selection of Inverter

Motor driven by the inverter is: JR 127- 8 115k W

Rated voltage: 380V

Rated current: 227A

In accordance with: the principle of rated output current of inverter ≥ motor rated current×1.1

227×1.1=249.7A

Check ALPHA6900 serie4s inverter sample:

Rated output current of capacity 132kVA: 255A

Rated output current of capacity 160k VA: 302A

Considering both the environment of the mine and the transportation condition, it is finally decided to choose the inverter with the capacity of I60kVA.

Model: ALPHA6900-3160G

4.2 Selection of PLC (programmable logic controller)

Through comprehensive consideration of up over-winding, down over-winding, manual up, manual down, automatic up, automatic down, normal stop, emergency stop, safety circuit, hydraulic station control, disc valve control, various operation indicators and backup indicators as well as mutual interlock between various operating modes and certain redundancy, it is finally decided to choose the Mitsubishi PLC (programmable logic controller) with 48 points.

Model: FX2N-48M-001

4.3 Selection of Energy Feedback Unit

4.3.1 Selection of Braking Voltage

If the chosen braking voltage is too low, when the voltage of the power system increases, it tends to cause malfunction of the braking unit. If the chosen braking voltage is high, it tends to cause threat to the safe operation of equipment. For a 380V system, a 700V braking voltage is generally chosen.

4.3.2 Selection of Braking Current

Braking current refers to the DC current flowing through the braking resistance and braking unit during the braking.

Basis of selection: the braking must be able to absorb all the renewable energy of the motor.

Braking absorption power (U×I) = renewable energy of the motor (watt)=1000×P×η

P____ Motor rated power (kW)

U____DC operating point of the braking unit, it is generally 700V

I____ Braking current (A)

η____ Conversion efficiency of mechanical energy during feedback, and generally take η=0.7

Through calculation, we get: I=115

4.3.3 Power Selection

The renewable energy of the motor must be absorbed and fed back to the power system.

$P_R=P\times Kf\times\eta\times\varepsilon$

P_R_____Power of the feedback unit (Kw)

η____ Conversion efficiency of mechanical energy during feedback, and generally take η=0.7

ε____ Braking power consumption safety coefficient, take ε =1.4

Kf____ Braking frequency, it refers to time proportion of the regenerative process in the whole operation of the motor

By referring to related material take Kf as 60%

Through calculation, we get P_R =67.62 kW

Select power of the feedback unit as 70 kW

5. Transformation Effect

5.1. Operation Effect

After the system has been put into operation, the winch has had convenient operation and stable motion, and the environment temperature and noise of the winch control room have been greatly improved, which has provided a great environment for the operator.

5.2. Energy Conservation Effect

During January to May of 2008, the hoisting unit consumption was 2.92 kilowatt hour/t; during January to May of 2009, the hoisting unit consumption was 1.66 kilowatt hour/t. The unit consumption had decreased by 1.26 kilowatt hour/t, and the decrease rate of unit consumption was 43.15%. In 2008, 132,334 tons of ores were lifted, 166,700 kilowatt hours of electricity were saved, and in accordance with the electricity price of RMB 0.528yuan/ kilowatt hour, an electricity cost of RMB 88,040 has been saved.

6. Conclusion

Application of the frequency-conversion system in the shaft hoist system can solve speed regulation and start problems, realize soft start and soft stop, reduce mechanical shock and make operation more stable and reliable; the impulse current during start and acceleration shifting is smaller, which has a reduced impact on the power system, simplified operation and reduced labor intensity of the workers; the operation speed curve presents a S-shape, which makes the acceleration and deceleration smoother without impact sensitivity; it has complete safety protection functions, and in addition to common protection against over-voltage, under-voltage, overload, short circuit and temperature rise, it is also equipped with interlock protection and automatic speed-limit protection. In the hoist used in the inclined shaft, the frequency-conversion speed regulation system is used to replace the series resistance speed regulation system, which is a new approach to increase the technology content of hoist used in inclined shaft of mine and also to explore new way of energy conservation.