Application of Alpha 6000 Inverter in SLOF (Shengli Oil Field)

I. Introduction

At present, the most common pumping equipment used in the oil field is beam kowtow pumping unit, which also has the biggest number. However, the traditional kowtow unit has various problems such as huge start impact, big consumption during operation, “big car Mara” and low efficiency. In addition, the oil well also has complicated situation, phenomenon like thickened oil, paraffin precipitation and stuck sand are common, and situations like broken rods and burnt motor are frequent. There is no reliable protection for the motor, and the equipment has a huge maintenance. Therefore, current pumping unit needs urgent transformation.

The frequency-conversion governor has low-speed start, and the rotation speed can be smoothly regulated within a wide range. It also has complete protection functions for the motor, such as protection against short circuit, overload, over-voltage, under-voltage and stalling, it can effectively protect the motor and mechanic equipment, and it has various advantages such as stable and reliable operation as well as increased efficiency. It is an ideal scheme for transformation of pumping unit, and its effects in application are obvious.

II. Basic Principle of the Inverter:

1. The principle of motor speed regulation

From the theory of motor we know that its formula of rotation speed is:

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

Where: P—Pole pairs of the motor;
s - Slip ratio;
f - Power supply frequency;
n - Rotation speed of the motor

From the above formula we can see that the rotation speed of the motor is almost in proportion to the frequency, and by changing the frequency, the rotation speed of the motor can be smoothly regulated; for the inverter, its frequency has a wide range of regulation, which can be regulated within 0～400Hz. Therefore, the rotation speed of the motor can be regulated within a wide range.

Of course, after the rotation speed is increased, the impact on the bearing and winding should be considered to prevent excessive abrasion and heating of the motor. Generally, the maximum frequency is set to be 50Hz or 65Hz.

2. Main circuit schematic diagram of the ALPHA inverter

The power device of ALPHA inverter is the IGBT of Siemens, and the core controller is the Hitachi H8 single chip, which has stable and reliable quality.

The ALPHA inverter we use now is the AC—DC—AC voltage source inverter. Its electric circuit is shown in FIG. 1.

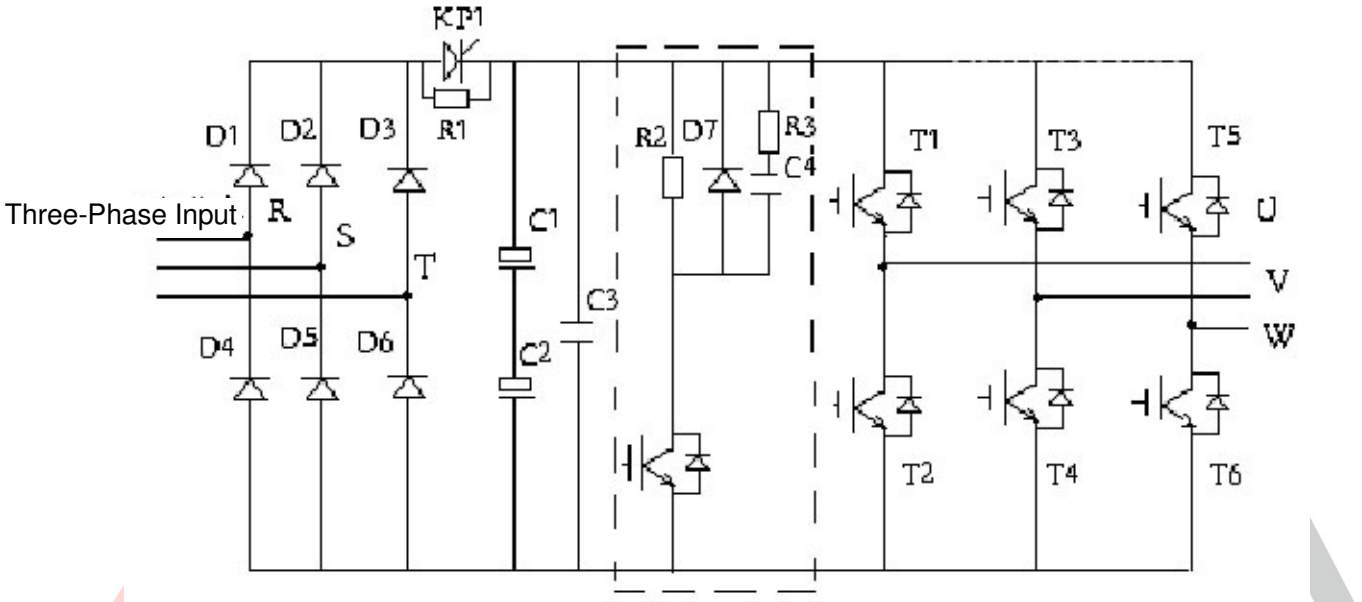


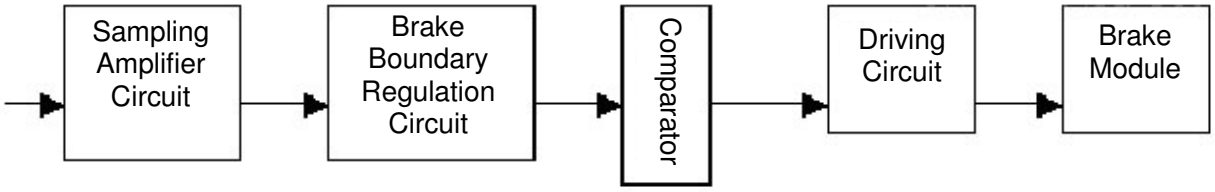
FIG. 1

III. Difficult point of inverter in the pumping unit

1. The motion of the pumping equipment is repeated lifting up and down, and one stroke requires one lifting. Its power mainly comes from the two very heavy steel sliders driven by the motor. When the slider is lifted up, it works as a leverage to deliver the pumping unit into the well, and when the slider descends, the sucker rod lifts the oil to the well mouth.

2. Due to fixed rotation speed of the motor, during descending of the slider, the load is reduced, and the energy generated during the driving of motor will have no place to release, so it will definitely enter the regeneration state, which might cause voltage increase of the bus bar in the main circuit; repeated high-voltage impact tends to damage the master device of the inverter, including the electrolytic capacitor and power module. Therefore, a brake circuit should be added to timely release the regenerated energy and ensure the equipment will be able to work under safe voltage.

3. The regeneration brake circuit is the commonly called brake circuit. As shown in the dotted frame in FIG. 1, it includes the comparison circuit, brake module and the brake resistor. Its control block diagram is as the following.



We conduct sampling and amplification of the main circuit, compare it with the reference voltage, and break over the brake unit at 1.1Ue (Ue refers to the rated bus bar voltage value) and turn it off at 1.05 Ue through regulation of the potentiometer. In this way, voltage of the main circuit can be controlled to ensure it operate within the permitted range.

4. Because the brake module controls the voltage of the main circuit through unijunction, its reliable operation is critical. The absorbing circuit should be well made, because the brake resistor tends to have long lead, and its lead inductance and spike voltage are increased correspondingly. Therefore, R, C and D absorbing circuits are adopted, and R3 and C4 in the FIG. are used to absorb the spike voltage generated by the lead inductance, and the added fast recovery diode is used to provide path for the inverted voltage generated on the two ends of the brake resistor when the brake unit ends. During frequent operation of the brake unit, an interference voltage tends to be generated, which might cause unwanted break-over of module and damage. Therefore, it is very necessary to add anti-interference capacitor on the input end of the signal to absorb the mis-break-over of module caused by interfered signal, and in general, non-inductive capacitor of 0.01uF is an appropriate choice.

5. Due to current-limiting from the brake resistor, the brake unit generally does not have big current, and around 100A would be enough. Because the brake resistor has to operate once within each stroke, it should have enough power to ensure long-term and reliable use, and 10Kw/80Ω electric stove wire is generally chosen.

IV. Technical Requirement for the Pumping Equipment in the Oil Field

We have selected the early, middle and late-phase of the well to conduct feasibility analysis of transformation, and we have successfully applied it in many occasions.

1. In the early phase of the well, because oil extraction just starts, the oil reserve is big and feed liquid is adequate. In order to increase efficiency, we have adopted the method to increase the rotation speed, and make the inverter operate under 65Hz with 1/3 increase in frequency. Correspondingly, the rotation speed of the motor has increased by 30%m its oil production has increased as well, its comprehensive oil productivity can be 20% higher than production under the power frequency, and the work efficiency has increased by 1.2 times. It is welcomed by the workers in the oil field.

2. In the middle and late-phase of the well, due to reduction of oil reserve in the well and inadequate feed liquid, if the motor still operates under the power frequency, it will definitely cause waste of energy and unnecessary consumption. Therefore, we have adopted the method to reduce the rotation speed and the stroke. In general, the inverter operates under the frequency of 35~40Hz, and in this way, the rotation speed of the motor can be reduced by 30%; in addition, because pumping equipment generally has a small load, its energy efficiency can reach about 25%. The power factor is increased and the reactive loss is reduced.

3. In the meantime, the inverter has the soft start/soft stop function. When the motor starts, the mechanic impact on the sucker rod is reduced, and it can stop with protection against thickened oil, paraffin precipitation and stuck sand, and in this way protecting the motor and mechanic device, reducing working amount of maintenance and preventing broken rods. The inverter also has reliable protection against over-voltage, under-voltage, overload, short circuit, and stalling of motor, which will help increasing the service life of the motor and reducing abrasion of the mechanic device.

In conclusion:

The pumping unit has adopted frequency-conversion governor, which can not only increase the efficiency and oil production, but also save energy and protect the motor and equipment. It has very broad prospect of application. In China, there are many pumping units, and we believe frequency-conversion governor will play an important role

The FIG. below is the photo of the Alpha special pumping unit inverter applied in SLOF (Shengli Oil Field):

V. Application of Alpha Special Pumping Unit Inverter in SLOF (Shengli Oil Field)

In May, 2004, Mine Four of the Sinopec SLOF (Shengli Oil Field) installed Alpha inverters (ALPHA6000) in 36,280 pumping units (working system of 56*3*4.5). Through more than two months' observation, it has had great performance in operation. Based on the principle of frequency-conversion speed-conservation, this device has adopted microcomputer control, which has realized energy conservation, efficiency increase and automation under the operating mode of big inertia and variable load of the pumping unit. The electrical parameter dynamic balance tester (the error is 0.5% of the standard value) was used to measure and compare the electric quantity before and after device operation. The specific process is as the following:

1. Operate the pumped well under the situation of changing the working system

   The device operated under variable frequency, during which the frequency was reduced from 50Hz to 32.5Hz, and the stroke frequency was reduced from 4.5 times to 3 times. Daily saved active power was 40.32KWh, the energy conservation rate was 28.33%, the power factor was increased by 0.13, and the unit consumption of fluid production was reduced by 0.79.

Operating Frequency	Working System	Active Power	Reactive Power	Power Factor	Daily Consumption of Energy	Daily Fluid Production	Daily Unit Consumption
50	56*3*4.5	5.93	7.43	0.624	142.32	32.3	4.41
32.5	65*3*3	4.25	3.73	0.749	102	28.2	3.62
Comparison		-1.68	-3.7	0.125	-40.32	-4.1	-0.79

2. Operate the pumped well with different stroke speeds while the same stroke frequency:

   Ensure the original stroke frequency was still 4.5 time, by setting different uplink/downlink frequency, the uplink/downlink speed was changed to adapt to the situation in a single well. Measure related data during the operation, the statistics of which is as the following:

Uplink/Downlink Frequency	Working System	Active Power	Reactive Power	Power Factor	Daily Consumption of Energy	Daily Fluid Production	Daily Unit Consumption	Uplink/Downlink Speed
55/40	56*3*4.5	5.76	4.77	0.77	138.24	33.41	4.14	V Uplink > V Downlink
55/35	56*3*4.5	5.28	4.54	0.759	126.72	32.78	3.87	V Uplink > V Downlink
40/55	56*3*4.5	5.92	4.61	0.789	142.08	34.88	4.07	V Uplink < V Downlink
40/50	56*3*4.5	5.56	4.44	0.781	133.44	32.53	4.10	V Uplink < V Downlink

3. Comparison results of the practical application and measured data

a. Through comparison of the measured data, this inverter can realize increase of daily fluid production by ensuring the original operation parameters. It presents the optimized trend of reduced daily consumption of energy. Its maximum daily fluid production can reach 34.88 ㎥ with an increase of 2.38 ㎥ and an increase rate of 6.8%; its minimum daily consumption of energy can reach 126.72KWh with an energy conservation rate of 10.96%; its unit consumption of fluid production was more than 0.4, which satisfies the requirement of oil production, energy conservation and decrease of consumption.

b. During operation, this device also has other characteristics:

① Zero start and soft start function, it can reduce the impact of the start of the pumped well on the power system, increase the service life of the motor, and reduce maintenance cost of the equipment.

② It satisfies the requirement of the oil production process. You can set any stroke frequency as well as the up and down stroke speed, in this way reducing the leaking coefficient of the pump during the lifting and making the pumped well operate under the optimal state.

③ The operation interface is simple and direct, which is equipped with the key interlock function to prevent mis-operation of the employee and protect the complete functions, and it also has the alarm function.