Energy Saving Effect of Small Water Station Motor in Enterprise

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Abstract. In this paper, the electric motor energy-saving transformation system of an enterprise of CNR is taken as the carrier, and the vertical centrifugal pump motor is taken as the object of energy-saving transformation. The operation of the existing working motor in the water station is investigated and the working parameters are measured and studied. The existing motor condition is transformed into energy-saving system. And the energy-saving transformation scheme, data calculation and economic benefit analysis of the whole energy-saving system are determined.

Keywords: Energy-Conservation; PMSM; energy efficiency.

1. Introduction

Energy saving and emission reduction are topics of common concern in today's world. With the rapid development and rapid improvement of modern industrial production, high efficiency and low energy consumption have become the most important pronoun for an enterprise. However, in the context of high efficiency, there are a series of problems such as irrational use of energy, noise pollution, etc., which restricts the development of enterprises, and energy saving is an important choice to alleviate the contradiction of energy constraints. The power consumption of motor system accounts for a large part of the total power consumption in the world, which needs close attention. Permanent magnet synchronous motor has the advantages of simple structure, easy maintenance, small moment of inertia, high power density and so on. With the development of material technology, it has been widely used in the field of high-performance motor control which focuses on efficiency and rapid response[1].

2. The Whole Scheme Design of Energy-saving System

According to the data and theoretical analysis of the previous measurement, 37 three-phase asynchronous motor driving the water supply pump of the second water station is selected as the transformation object, and the specific transformation scheme is proposed to study the energy-saving system transformation of the pump motor. Motor water pump is the core component of water supply system in water station[2], and the selection of motor is also the key to determine the operation efficiency of water station. Only when we have a very deep understanding and Research on the water supply system of the water station, can we reasonably give the operation parameters of the motor in the system, and select the correct type of motor from the existing data of the water station and make it always in the operation of energy saving and high efficiency. The water supply pressure of the main pipe network is required to be between 0.32mp and 0.42mp in the water station, and it is generally required to be stable at about 0.36mp. When two motors are all directly started, the pressure of the main pipe network...
sometimes exceeds 0.42mp, which will impact the external part of the pipeline and cause pipeline rupture. The focus of the project is to replace one of the 37 motors with the same rated three-phase permanent magnet synchronous motor, which is started by frequency conversion and used as auxiliary water supply to make the pressure of the main network meet the water pressure requirements of the pump station. The main methods of motor energy-saving transformation are as follows, using high-efficiency energy-saving motors, such as replacing the old motors with the YE3, Y2, Y2E, YX ones, using three-phase permanent magnet synchronous motors, using soft starters for frequently started motors, lowering the power supply voltage and adjusting the power supply voltage from 410v to 380V, taking frequency converter speed control system for water pump motors, taking local reactive compensation measures, etc. The design scheme of the energy-saving system is divided into energy-saving transformation of permanent magnet motor, energy-saving transformation of YE3 high-efficiency motor and energy-saving of frequency control.

3. Energy-saving System Design

3.1. Characteristics of Frequency Conversion and Constant Pressure Water Supply Control

Constant pressure water supply is a typical control system in the production and life of modern society, which is widely used in the process of urban heating and water supply [1]. The energy-saving water supply control system is composed of clean water tank, control valve, constant pressure water supply control device, water supply pipe network and pump motor. For the water supply system of the pumping station of the water station, the actual running water pump motor mainly has two 37-phase three-phase asynchronous motors and four 45-kilowatt standby motor water pumps. Considering the operation efficiency of the water pump, the water supply pipe network is guaranteed. Constant pressure and high efficiency operation of the pump motor require the transformation of the original system, replacing the original pump in operation with a permanent magnet synchronous motor. As a speed control pump, it also uses a constant pressure water supply method to meet the lift requirements required for the water supply system to ensure the energy-saving effect of the operation. The water consumption in the production pipe network water supply system changes continuously with the time period, and the control of the water supply is strict. Therefore, the frequency conversion speed control device can realize the quick and smooth start of the motor and avoid the impact water pressure generated by the power frequency start. The water hammer effect is caused on the pipe network, which can protect and extend the use time of the motor and the water pump. The variable frequency constant voltage speed regulation can well meet this requirement well. Schematic diagram of water supply network is shown in Figure 1.

![Figure 1. Schematic Diagram of Water Supply Network.](image-url)
3.2. Overall Structure of Energy Saving System
The energy-saving water supply system regulates the output frequency of the frequency converter through the pressure closed-loop[3], and then controls the pump motor according to the frequency change, so that the pressure of the pump motor control pipe network reaches the pressure range value given by the system, and the main controller (constant pressure water supply controller) captures the output of the zero phase of the frequency converter and the output of the zero phase of the power frequency power supply. When the two voltage signals are at the same zero phase, the main control device (constant pressure water supply controller) will send system control instructions to switch between the power supply of frequency converter and power supply of power grid[4]. Overall structure of energy saving system is shown in Figure 2.

![Figure 2. Overall Structure of Energy Saving System.](image)

4. Energy Efficiency Analysis of Permanent Magnet Synchronous Motor

4.1. The relationship Between the Efficiency of the Motor and the Power Factor
For different load rates, the efficiency and power factor of the motor will change to achieve the highest operating efficiency and power factor. At a certain load rate, the power factor at the highest efficiency is at a fixed value. The change of load rate has little effect on the power factor and output efficiency of permanent magnet synchronous motor. The power factor varies from 0.85 to 0.98, and the efficiency varies from 92% to 96%. The change of the load rate has a great influence on the common asynchronous motor. The power factor of the common asynchronous motor is mainly related to the load factor, the voltage and the characteristics of the motor. Except that it is a certain value at the rated power, other conditions are light load or when no-load operation, the power factor will be lower. In this case, the line reactive power loss will be large, and the burden on the transformer will increase.

4.2. Data Analysis of Motor
The data measured in this paper are mainly divided into three parts: the data of two ordinary asynchronous motors Y225S-4 running at the same power frequency, the data of one ordinary asynchronous motor running at the power frequency and the data of another ordinary asynchronous motor using the frequency conversion control cabinet to control the frequency conversion start, the data of one ordinary Y225S-4 asynchronous motor running at the power frequency and the data of one tyxc225s-4 permanent magnet synchronous motor running at the frequency conversion. We will make benefit analysis on the measured data of each link.

(1) Two common models Y225S-4 asynchronous motor run at the same time
Table 1. The two running measurement comparative data of 37 kilowatts ordinary motor.

|                | Voltage (V) | Current(A) | Active power (kW) | Power factor cos φ | Pipe network pressure (MP) |
|----------------|-------------|------------|-------------------|--------------------|----------------------------|
| 1# pump power frequency | 393         | 50         | 30                | 0.83               | 0.42                       |
| 2# pump power frequency | 392         | 49         | 28                | 0.82               |                            |

When the pumps of two ordinary motors are running at the same time, the total network pressure can reach 0.42MP, which is the upper pressure limit required by the factory. Assuming an annual running time of 7200h, the factory electricity price is 0.7 yuan/kW·h.

Power frequency 1# pump annual power consumption is

\[ W = TP_1 = 7200 \times 30 = 216000kW \cdot h \]  \hspace{1cm} (1)

Power frequency 1# pump annual electricity consumption fee is

\[ M_1 = WC_e = TP_1C_e = 7200 \times 30 \times 0.7 = 151200 \text{ yuan} \] \hspace{1cm} (2)

According to (1) and (2), Power frequency 1# pump annual power consumption and its fee are 201600kW·h and 141,120 yuan respectively. The total power consumption of the two pumps is 417600kW·h, and the annual operating electricity cost is 292,320 yuan.

(2) One ordinary asynchronous motor power frequency operation and another ordinary asynchronous motor frequency conversion operation

Table 2. The two running measurement comparative data of 37 kilowatts ordinary motor.

|                | Voltage (V) | Current(A) | Active power (kW) | Power factor cos φ | Pipe network pressure (MP) |
|----------------|-------------|------------|-------------------|--------------------|----------------------------|
| 1# pump power frequency | 394         | 37.6       | 24                | 0.87               | 0.37                       |
| 2# pump power frequency | 393         | 50         | 30                | 0.83               |                            |

According to (1) and (2), Power frequency 1# pump annual power consumption and its fee are 172800kW·h and 120,960 yuan respectively. The total power consumption of the two pumps is 388800kW·h, and the annual operating electricity cost is 272,160 yuan.

(3) While the Y225S-4 asynchronous motor is running at the power frequency, the TYCX225S-4 permanent magnet synchronous motor runs at a variable frequency

Table 3. The two running measurement comparison data of 37 kilowatts motor.

|                | Voltage (V) | Current(A) | Active power (kW) | Power factor cos φ | Pipe network pressure (MP) |
|----------------|-------------|------------|-------------------|--------------------|----------------------------|
| 1# pump power frequency | 393         | 50         | 30                | 0.83               |                            |
| 2# pump power frequency | 394         | 25         | 15.1              | 0.94               | 0.35                       |

According to (1) and (2), Power frequency 1# pump annual power consumption and its fee are 108720kW·h and 76,104 yuan respectively. The total power consumption of the two pumps is 324720kW·h, and the annual operating electricity cost is 227,304 yuan.

In summary, after the transformation of the permanent magnet synchronous motor by frequency conversion speed control, the annual operating electricity cost is saved by 65,016 yuan per year compared with the original two-pump operation. Compared with the use of two asynchronous motors at the same time, the situation saved by 44,856 yuan a year, the energy-saving benefits are obvious.
4.3. Theoretical Economic Benefit Analysis

Table 4. The rated data of permanent magnet synchronous motor (TYCX225S-4).

| Parameter name      | Unit | Rated value |
|---------------------|------|-------------|
| Power rating $P_N$  | kW   | 37          |
| Synchronous speed $n_N$ | Rpm | 1500        |
| Rated frequency $f_N$ | Hz  | 50          |
| Rated efficiency $\eta$ | %  | 94          |
| Rated voltage $U_N$  | V    | 380         |
| Rated current $I_N$  | A    | 62.9        |

According to Table 4 data of permanent magnet motor, the energy saving of high-efficiency permanent magnet motor is

$$W = \left(\frac{1}{\eta_L} - \frac{1}{\eta_H}\right)TPNK_r$$

(3)

Where: \(W\) – Annual electricity consumption, \(kW \cdot h\),
\(\eta_L\) – Efficiency of General Motor, \(%\),
\(\eta_H\) – Efficiency of permanent magnet motor, \(%\),
\(T\) – Annual operating hours, \(h\),
\(K_r\) – Annual average load rate of motor, \(K_r \leq 1\).

The annual energy saving cost of selecting high efficiency motor is

$$M_Y = WC_e$$

(4)

Where: \(M_Y\) – Annual electricity saving cost, yuan,
\(C_e\) – Unit price of plant electricity, yuan/(\(kW \cdot h\)).

The recovery cycle using a permanent magnet synchronous motor is

$$Y_HL = (C_H - C_L) / M_Y$$

(5)

Where: \(Y_HL\) – Recovery period of permanent magnet motor, year,
\(C_H\) – Cost of permanent magnet motor, yuan/per motor,
\(C_L\) – Cost of General Motors, yuan/per motor.

According to the analysis of the measured field data, when the load rate \(K_r = 80\%\), the efficiency of the ordinary asynchronous motor of 2# pump is \(\eta_L = 0.918\), the efficiency of the permanent magnet motor \(\eta_H = 0.958\), the price of one ordinary asynchronous motor is 8000 yuan, and the price of one TYCX225S-4 permanent magnet motor is 15000 yuan. According to the formula (3), (4) and (5), the energy saving of 2# pump motor is replaced by the permanent magnet synchronous motor is

$$W = \left(\frac{1}{\eta_L} - \frac{1}{\eta_H}\right)TPNK_r = \left(\frac{1}{0.918} - \frac{1}{0.958}\right) \times 7200 \times 37 \times 0.8 = 9696.96kW \cdot h$$

Annual electricity savings is \(M_Y = WC_e = 9696.96 \times 0.7 = 6787.872\) yuan

Repayment period for purchasing a 37KW high efficiency permanent magnet motor is

$$Y_HL = \frac{C_H - C_L}{M_Y} = (15000 - 8000) \div 6787.872 = 1.031\ years$$

By calculation, the recovery time of motor cost will take about 1 year, and when the efficiency of motor is improved to a certain extent, the longer the annual operation hours are, the higher the electricity price is, the shorter the recovery period of motor is, and the more reasonable the scheme of permanent magnet motor is.
5. Summary
In this paper, the vertical centrifugal pump motor is taken as the object of energy-saving transformation. The method of combining frequency control and energy-saving control with the replacement of three-phase permanent magnet synchronous motor is used to transform it. The feasibility is verified by data calculation and economic benefit analysis.

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