Research on Harmonic Treatment of Intermediate Frequency Furnace

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Abstract. In order to solve the problem of power quality caused by harmonics in the factory, this paper mainly focuses on the research of the current situation of the harmonics in the medium frequency furnaces of the factory forging workshop, analyzes the harmonic content of each medium frequency furnace, and adopts a new W-APF active power filter for harmonic suppression. The experimental results indicate that the harmonic content of the medium frequency furnace meets the requirements of the national harmonic standard of power quality public power grid after W-APF filtering.

Keywords: Intermediate frequency furnace harmonics; harmonic content rate; APF active power filter.

1. Introduction
In recent years, with the accelerating industrialization process, nonlinear electronic products such as power electronic devices have been widely used in industrial and control fields, but the harmonic pollution of the power system has become increasingly serious. The medium frequency induction heating device (medium frequency furnace) is a fast and stable metal heating device, which converts the three-phase power frequency alternating current into single-phase intermediate frequency alternating current by the frequency conversion device[1]. The rectification frequency conversion device is the core equipment of the intermediate frequency furnace, but the harmonics generated by it will cause great harm to the electrical equipment of the power grid. The motor can generate additional power loss and heat, and cause interference to relay protection, automatic control devices, etc., which may cause malfunction, and harmonics may be amplified in the reactive compensation capacitor circuit, resulting in overload or even damage of the capacitor. Therefore, the harmonic problem of high-power intermediate frequency furnace cannot be ignored.

1.1. Medium Frequency Furnace Working Principle
The intermediate frequency power supply first outputs the 50Hz AC power provided by the power grid to the DC through the bridge rectifier circuit. After filtering, the intermediate frequency (500-1000Hz) current is generated by the thyristor rectifier inverter and sent to the intermediate frequency furnace coil, and the furnace body (coil) An intermediate frequency alternating magnetic field is generated in the middle, so that the metal in the furnace body generates eddy current, and the eddy current causes the metal to generate a large amount of heat to melt the metal, and the heating method is more than 30% higher than the power frequency heating efficiency.
1.2. Intermediate Frequency Furnace Harmonic Causes

In the current power system operation, the harm of power harmonics to the users of the power network exists. As a way of power hazard, certain pollution will occur, so it is necessary to pay attention to it. Among them, in the intermediate frequency furnace in the inverter process, the external input 380V/50Hz power frequency power supply is uncontrollable and rectified into DC voltage through the three-phase bridge, and the capacitor is filtered and the high-power transistor switching element is inverted for variable frequency AC voltage. In the rectifier loop, the input current waveform is irregular rectangular wave, which is divided into fundamental wave and each harmonic according to the Fourier series. The harmonic frequency is usually 6n±1 higher harmonic, in which the higher harmonic will interfere with the input power system[2]. If the power supply side reactance is sufficiently small and the commutation overlap angle is "negligible, then the nth harmonic is 1/n of the fundamental current. In the output circuit of the inverter, the output current signal is a pulse waveform modulated by PWM carrier signal. For the GTR high-power inverter component, the PWM carrier frequency is 2-3 kHz, and the PWM maximum carrier frequency of the IGBT high-power inverter component can reach 15 kHz. Similarly, the output loop current signal can also be decomposed into only the fundamental and other harmonics.

1.3. Intermediate Frequency Furnace Harmonic Calculation

1) Intermediate frequency furnace primary side
The intermediate frequency furnace power supply voltage distortion is extremely unlikely, and the current harmonic distortion is highly probable. Power calculation can be based on

\[
\begin{align*}
P &= U \cos \alpha_1 \\
S &= UI \\
P_h &= \frac{P}{S} = (I_1/I) \times \cos \alpha_1
\end{align*}
\]

2) Secondary side of intermediate frequency furnace
Power cannot be generated between voltages and currents of different harmonics, and its product is zero. Then, in addition to the fundamental power, the harmonic power is calculated[3]. Can write

\[
\sum_{n=1}^{\infty} U_n \times I_n \times \cos(n\theta)
\]

2. Current Status of Power Supply in Intermediate Frequency Furnace

Because most of the factory's workshops are widely distributed, the power supply network is under pressure. In this regard, the quality of power supply in the workshops of the factory must be taken seriously. However, the influence of different workshops on the grid is different due to different equipment[4]. There are many medium frequency furnace instruments in the forging workshop, which have a great impact on the power grid. Therefore, the installation of several medium-frequency furnace equipment in the forging workshop.

2.1. 2T Die Forging Intermediate Frequency Furnace

The Fluke Power Quality Tester is used to test the 2T die forging intermediate frequency heating equipment in the forging workshop. The test results are shown in Table 1. It can be seen from Table 1 that the substation voltage harmonic THD is about 11.6%, and the current harmonic of the grid is about 27.4%. Among them, the 5th, 7th, 11th, 13th and 17th harmonic currents account for a large proportion, indicating that the harmonic pollution of the power grid is serious.
Table 1. 2T die forging heating equipment power quality testing.

| workshop   | Device name                     | device ID |
|------------|---------------------------------|-----------|
| blacksmith | 2t die forging intermediate frequency heating | 17 changes |

| Test Data | Voltage harmonics [%] | Current harmonic [%] |
|-----------|-----------------------|----------------------|
|           | A         | B         | C         | A         | B         | C         |
| total     | 13.4      | 11.6      | 11.6      | 27.5      | 27.4      | 27.5      |
| 5 times   | 5.5       | 4.9       | 4.7       | 24        | 24        | 23.9      |
| 7 times   | 3.1       | 2.8       | 2.6       | 6.4       | 6.3       | 6.7       |
| 11 times  | 4.4       | 3.9       | 3.9       | 7.4       | 7.3       | 7.3       |
| 13 times  | 3.6       | 3.3       | 3.2       | 4.5       | 4.5       | 4.6       |
| 17 times  | 4.1       | 3.6       | 3.5       | 4.4       | 4.3       | 4.3       |

Figure 1 is a histogram of three-phase current harmonics of 2T die forging grid. It can be clearly seen from the figure that the 5, 7, and 11 current harmonics of the grid are large. The current harmonics of the grid should be effectively treated to improve the power quality of the grid.

Figure 2 is a histogram of the three-phase voltage harmonics of the 2T die forging grid. It can be clearly seen from the figure that the 5, 7, and 11 voltage harmonics of the grid are large. The grid voltage harmonics should be effectively treated to improve the power quality of the grid.

Figure 3 is a three-phase frequency fluctuation diagram of a 2T die forging grid. It can be seen from the figure that the maximum value of the three-phase frequency fluctuation of the grid is about 50.02, and the minimum value is about 49.96. The fluctuation range of the grid is within the allowable range of national frequency fluctuations in China.
3. Medium Frequency Furnace Power Quality Improvement Program

The compensation of the intermediate frequency furnace harmonics can be managed by installing a filter. According to the structure and principle of the filter, it can be divided into active filtering and passive filtering\[^5\]. Passive filter (PPF) is a kind of compensating device composed of a capacitor, a reactor and a resistor through a series and a combination. The basic principle is to absorb harmonics through the low impedance characteristic of the capacitor reactance resonance, thereby achieving the purpose of filtering. The active filter (APF) itself is also a power electronics device that compensates for harmonics of varying magnitude and frequency as well as varying reactive power. The basic principle is to detect the harmonic current from the compensation object, and then generate a compensation current equal to the harmonic current and opposite polarity to the current provided by the grid, so that the total current injected into the grid contains only the fundamental component\[^6\]. The filtering effect of the active filter is better than that of the passive filter. It is suitable for the environment with complex harmonic components and large harmonic changes. Due to the characteristics of the harmonic current generated by the intermediate frequency furnace, this paper uses the active filter pair. The harmonics of its rectifier are compensated.

The quality of the medium frequency furnace power grid in the forging workshop is in addition to the lower harmonics, as well as higher harmonics. The 8000T medium frequency heating equipment, 17-variable and 2T die-forging grid voltages of the workshop are 0.66KV, and 5, 7, and 11 current harmonics are generated in the power grid, and the current harmonics are large. Some dynamic harmonics need to be active. Filter to filter out. This paper uses W-APF active power filter, which can realize intelligent filtering of harmonics, dynamic reactive power compensation and balanced three-phase load function. With advanced technology, it can track compensation continuously, follow load change in 40 $\mu$s, and complete compensation in 10 ms. Filter performance is not affected by system impedance. The harmonic compensation performance is not affected by the change of the grid frequency. The compensation capability is not limited by the grid voltage\[^7\]. It can still provide enough reactive power when the voltage is low.
Table 2. 4, 6 times single tuned filter parameters.

| Filter settings | Capacitance value [$\mu$F] | Inductance value [mH] | Resistance value [Ω] | Quality factor | Three-phase reactive power [kVar] |
|-----------------|-----------------------------|-----------------------|----------------------|---------------|----------------------------------|
| First group     | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |
| Second Group    | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |
| The third group | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |
| Fourth group    | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |
| Fifth group     | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |
| The sixth group | 353.698                     | 1.3538                | 0.0391               | 50            | 18.66                            |

Table 3. Install 4.6 filter harmonic suppression effect.

| Harmonic current | Injection system current [A] | System allows current [A] | Load current [A] | HRU before filtering [%] | Filtered HRU [%] |
|------------------|------------------------------|---------------------------|------------------|--------------------------|------------------|
| 5                | 49.8561                      | 44.4373                   | 120.3            | 4.0474                   | 1.6774           |
| 7                | 42.8527                      | 31.3675                   | 59.38            | 2.7969                   | 2.0184           |
| 9                | 4.1259                       | 14.3768                   | 5.35             | 0.324                    | 0.2499           |
| 11               | 30.1896                      | 20.9117                   | 38.21            | 2.8282                   | 2.2345           |
| 13               | 18.5432                      | 16.9907                   | 23.19            | 2.0285                   | 1.6221           |
| 17               | 12.5592                      | 13.0698                   | 15.53            | 1.7765                   | 1.4367           |
| 19               | 7.6407                       | 11.7628                   | 9.42             | 1.2043                   | 0.9768           |
| 23               | 5.951                        | 9.6717                    | 7.31             | 1.1313                   | 0.921            |
| 25               | 3.3743                       | 8.8875                    | 4.14             | 0.6964                   | 0.5676           |
| Total            | 79.4653                      | 171.4758                  | 144.16           | 6.6424                   | 4.4421           |

Figure 4. System current spectrum.  
Figure 5. Bus voltage spectrum diagram.

5. Conclusion
In this paper, several types of intermediate frequency furnaces in the factory forging workshop are used for harmonic detection, and the main influence harmonics are given. The W-APF active filter is installed for dynamic harmonic detection and treatment. After filtering, the main 5, 7, 11th harmonic is effectively reduced. After the management device is put into operation, the testing and evaluation of the third-party authorities ensure the investment income of the intermediate frequency furnace users and the quality of the governance project.

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